W. Bodenstein

INSTRUCTIONS GEI-19645-E

HC-25-A3 CATHODE RAY OSCILLOGRAPH

GENERAL ELECTRIC

FN-412-A (11-46)

INSTRUCTIONS GEI-19645-E

HC-25-A3 CATHODE RAY OSCILLOGRAPH

GENERAL ELECTRIC CO.

SCHENECTADY, N. Y.

November, 1948

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

INSTRUCTIONS GEI-19645-E

HC-25-A3 CATHODE RAY OSCILLOGRAPH

I. INTRODUCTION

The HC-25-A3 cathode ray oscillograph is an oscillograph for the observation and photographic recording of high speed transients such as produced by surge generators or by sudden changes in a circuit. Its visualizing elements are a pair of cathode ray tubes of hot cathode sealed off design whose screens may be photographed by a pair of cameras and simultaneously viewed by the operator.

II. DESCRIPTION

Photograph No. 1060326 shows an oblique front view, photograph No. 1060327 a rear internal view and photograph No. 1054619 the trip-surge generator used for coordinating it with a surge generator. The cabinet is about 27" x 36" x 70" and all controls are above the 30" level so that a table or desk may be built around it. The camera holder has two eyepieces so that operation may be conducted from either a standing or sitting position.

In the back two doors give easy access to all components and connecting cables are coupled to connectors on a narrow panel at the bottom. Near the top are the cathode ray tubes with a magnetic shield around them. Attached to the shield

are two metal boxes containing the resistance voltage dividers and the selector switches. Below this from left to right are the timing wave oscillator, the two sweep circuits and the time delay circuit. On the next lower level are the two 300 volt and two 850 volt power supplies for the sweep circuits. At the bottom are the 25 KV power supply for the cathode ray tube and a voltage regulator.

III. <u>SETTING-UP</u>

The oscillograph is shipped with all tubes packed separately. The small tube sockets are marked with the tube type numbers. The instruction book on the voltage regulator shows locations of its tubes.

The cathode ray tubes 5RP11A are installed as follows:

1. Remove top of magnetic shield.
2. Place tubes in shield in approximate position with accelerator ring terminals to left.
3. Connect leads to rings in same order in which they come thru right side of shield.
4. Connect other leads according to tag numbers to deflection terminals which are counted 1 to 5 in a counterclockwise direction.
5. Replace top of shield being careful to see that high voltage leads are properly placed.
6. Turn tubes so that ring terminals are on horizontal center line.

7. Adjust lengthwise so that screens are 2" back from front panel.

8. Adjust deflection and sweep leads for maximum separation from each other.

The camera holder is installed so that shutter solenoids pull upward to open shutters.

The DC calibration circuit is on the front panel and its four OA2 tubes mounted horizontally.

IV. CIRCUIT DESCRIPTION

1. Low Voltage Circuits, M-5112518

This shows the 115 volt wiring and is fairly obvious. A time delay relay provides a one minute interval for filament heating before high voltage circuits can be turned on. Another relay holds the 850 volt power supply off until the 300 volt is on. This is necessary for the protection of tubes in the sweep circuit which derive bias from the 300 volt circuit. The saturated core type voltage regulator provides ±0.2% regulation for the high voltage supplies.

2. High Voltage Circuits, P-5122173

This shows the excitation, bias, deflection and calibration circuits of the cathode ray tubes in detail and the interconnections of the sweep circuits and their associated circuits.

The cathode excitation consists of two sources, one a -4 KV double wave rectifier with a 3 MA divider for each tube

and a 21 KV voltage doubler circuit with 0.7 MA divider.

The intensity control potentiometer has another one in series with it mounted with its knob inside on an insulated sub panel. This is for adjusting the beam just under cutoff when the intensity potentiometer is turned up. Similarly for adjusting focus there are two internal potentiometers one on either side of the focusing control. These serve to adjust the focusing potentiometer into the best position in the voltage divider.

The DC calibration circuit derives its voltage from the sweep power supplies, holding it steady be means of four 150 volt OA2 regulator tubes in series. This gives 600 volts of which 500 volts in steps of 100 volts is used for calibration. The voltage is set by adjusting the current thru the wire wound resistors 2.5 MA by means of an external milliameter plugged into a jack in the ground side. The adjusting rheostat is set with a screw driver thru a hole in the front panel between the two DC control knobs.

The deflection selector switches provide forward and reversed connections of the deflection plates. This permits deflection in the same direction for either polarity of deflection voltage. Vertical bias on the deflection in either direction is obtained by control of the voltage on the plate which otherwise would be grounded.

The resistance voltage divider of the right hand tube provides 75 ohm termination for the deflection cable with ratio steps as shown. The left hand voltage divider provides 1000 ohm termination.

3. Power Supplies, M-5112517

These two chassis provide the various voltages needed by the sweep, calibration and bias circuits.

4. Time Delay Circuit, M-5112567

The main purpose of this unit is to provide two pulses, one for starting the sweep and the other for tripping the trip surge generator at some time interval later. It also has three relays which in conjunction with two push buttons and a shutter switch control the camera shutter and a second (zero line) sweep. The four combinations are listed on the print. Relay #1 is slowed up by series resistance and a weighted armature to give the shutters time to open before relay #2 closes to trip tube #1. If the red button (M-5112518) is pushed then relay #3 will close after relay #2 and send another pulse to terminal 12 for tripping the sweep. Relay #3 takes longer to close than the longest sweep and presumably the longest transient and therefore the second sweep should be a zero line. The interval between the two is short enough to give the illusion of a single picture.

The closing of relay #2 provides a positive pulse to terminal #12 which starts the sweep. A second pulse on

terminal #11 is produced by the tripping of the tube #2 some time later depending on the product of R.C. R is in steps geared to the sweep switch and C is a variable capacitor for fine adjustment of this interval whose purpose is to provide some zero line before the surge generator is tripped. The values of R shown in the table were chosen with the object of giving about the same length of zero line on all sweeps.

5. Trip Surge Generator, M-5112535 Photograph No. 1054619

This is a small Marx circuit surge generator with 14 KV per stage giving a negative 70 KV pulse output for tripping any large surge generator. The first gap is replaced by a GL4C35 thyratron which receives its tripping pulse from the time delay circuit previously described. Preliminary ionization for consistent tripping of the gaps is produced by the corona from a sharp point reaching from the positive side toward the negative sphere of the first gap.

6. Sweep Circuit, M-5112516

The purpose of this circuit is to produce two voltages of opposite polarity varying linearly with time over a range of some 500 volts which connected to the time axis plates of the cathode ray tube produce a linear time axis. Voltages and steady state currents are marked for each tube. Operation is as follows.

A pulse of positive polarity is received on terminal #1 from the time delay circuit or a pulse of either polarity

from some other source to start the circuit action. The polarity switch is set for the polarity of the initiating pulse in order to get a positive pulse output from tube #1 to trigger off the multivibrator tubes #2 and #3. The duration of the positive square wave output of tube #3 depends on C-1 which together with C-2 later in the circuit is varied over 11 steps by the sweep switch. Values are given in the table on the diagram. The output of #3 is inverted and amplified by #4 whose output in turn serves to cutoff tubes #5 and #6. Cutting off tube #5 causes it to put out a positive square wave of 125 volts which is used for driving the grid of the cathode ray tube. Cutting off tube #6 leaves #7 to discharge C-2 at a constant rate which results in a linear rise of negative voltage on the grid of #8. The output of #8 then drives the push pull tubes #9 and #10 which provide the final drive on the sweep plates.

This circuit is rather critically balanced insofar as C-1 and C-2 have to be matched. If C-1 is too small with respect to C-2 the sweep will stop short of the edge of the screen. If C-1 is too large with respect to C-2 the sweep will lose its linear character and slow up toward the end. When tubes #2, #9 or #10 are renewed their potentiometers may need readjustment.

Trouble shooting can best be started by checking to see if the various plate voltages are as shown on the diagram.

This circuit is also somewhat critical of the type of pulse which will trigger it. A steep front of 10 volts or so and uni-directional tail of average length is preferred. With slower fronts greater amplitude is required especially for the faster sweeps. Oscillations may cause disturbances in the multivibrator tubes #2 and #3 which will cause a shortened time axis or other irregularities.

V. PHOTOGRAPHIC RECORDING

The cameras are mounted on the front of the camera holder with control knobs to the right and are held in place by pairs of knurled nuts. The lens speed of F1.5 is required only on the faster sweeps. F4 or even F6 will give good results on the slowest ones. Eastman super pan XX35 mm film and D72 developer has been used for years although there may be some faster films now available.

The camera is made up of a Wallensak lens and an Eastman Kodak 35 camera. On the left side there is a small catch which may be turned 90 degrees to remove the top half of the film holder. The film spool is placed in the upper end and the film moved downward by turning the winding knob as shown by the arrow. When a roll is finished the winding knob will not turn. Then the film must be rewound into its original container before removal. Before re-rolling, the winding knob is pulled out about 1/8" to release the free wheel mechanism in it which keeps the film tight. Near the winding

knob there is a small button which must be pressed to allow winding up each new exposure. However, in this application two or three records may be taken on the space provided for an exposure by moving the film less than the full amount each time.

Solenoid operated shutters are located inside the camera holder. They may be turned off by means of the shutter switch on the oscillograph switch panel or by individual switches on the camera holder. The lens shutter is normally left open and all recording done with the solenoid shutter.

VI. OPERATION

Connecting cables all attach at the lower rear panel. A three conductor plug carries 115 volt 60 cycle supply and ground leads. Other coaxial cable plugs reading from left to right are:

1. resistance voltage divider for right hand tube
2. capacitance divider
3. pulse and bias to trip surge generator
4. for tripping sweep from outside sources of surge voltage
5. resistance voltage divider for left hand tube

The main and filament switch are closed first and after a minute for heating the 300 volt switch is closed. The 850

volt switch should be closed about 15 seconds later. This is because the 300 volt power supply filaments are supplied by its power transformer and it takes so long to establish the 300 volts. The 25 KV is turned on last without delay after the 850 volts. It is a good precaution to be looking in at the screens whenever turning on the cathode excitation and to keep one's fingers on the switch ready to turn it off in case of any trouble. If the cathode beam is established in a spot with any intensity it will melt a hole in the screen in a few seconds.

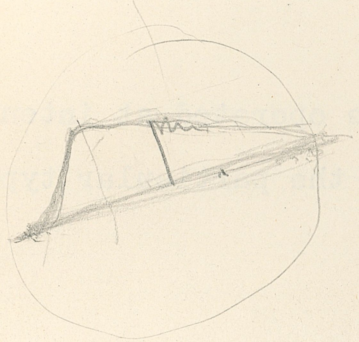
For long life the tube should be operated at intensities as low as will give good results for the particular type of work being done.

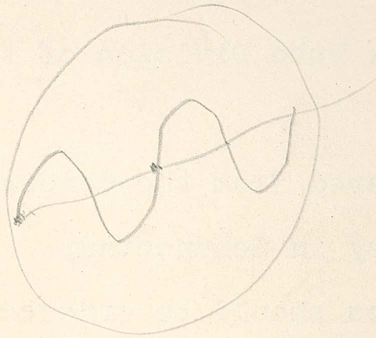
VII. RENEWAL PARTS

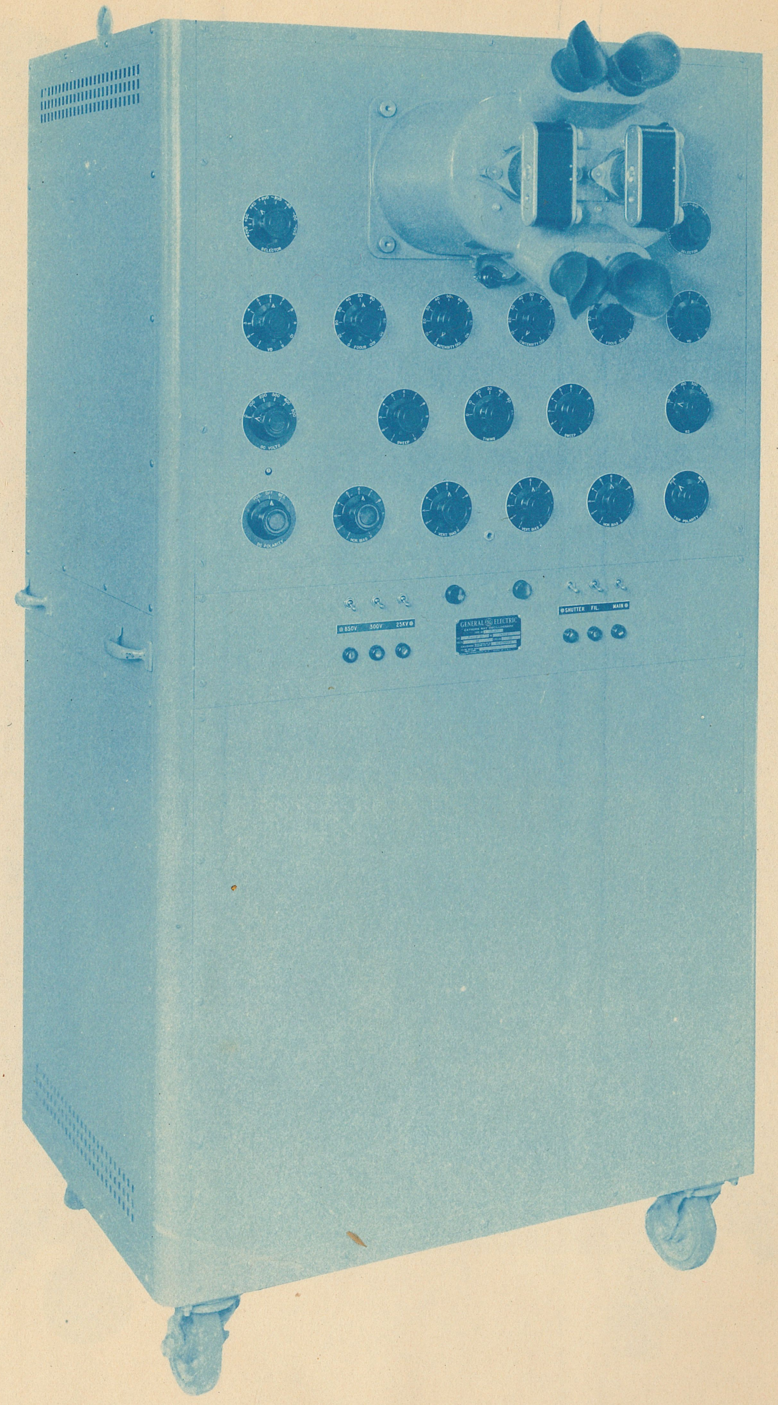
Order all tubes through the Tube Division of the Electronics Department.

All other parts may be ordered from the General Engineering and Consulting Laboratory in Schenectady.

The 5RP11A cathode ray tubes should be ordered with metallized screens as this gives from 30 to 90% greater intensity at about 20% higher cost.



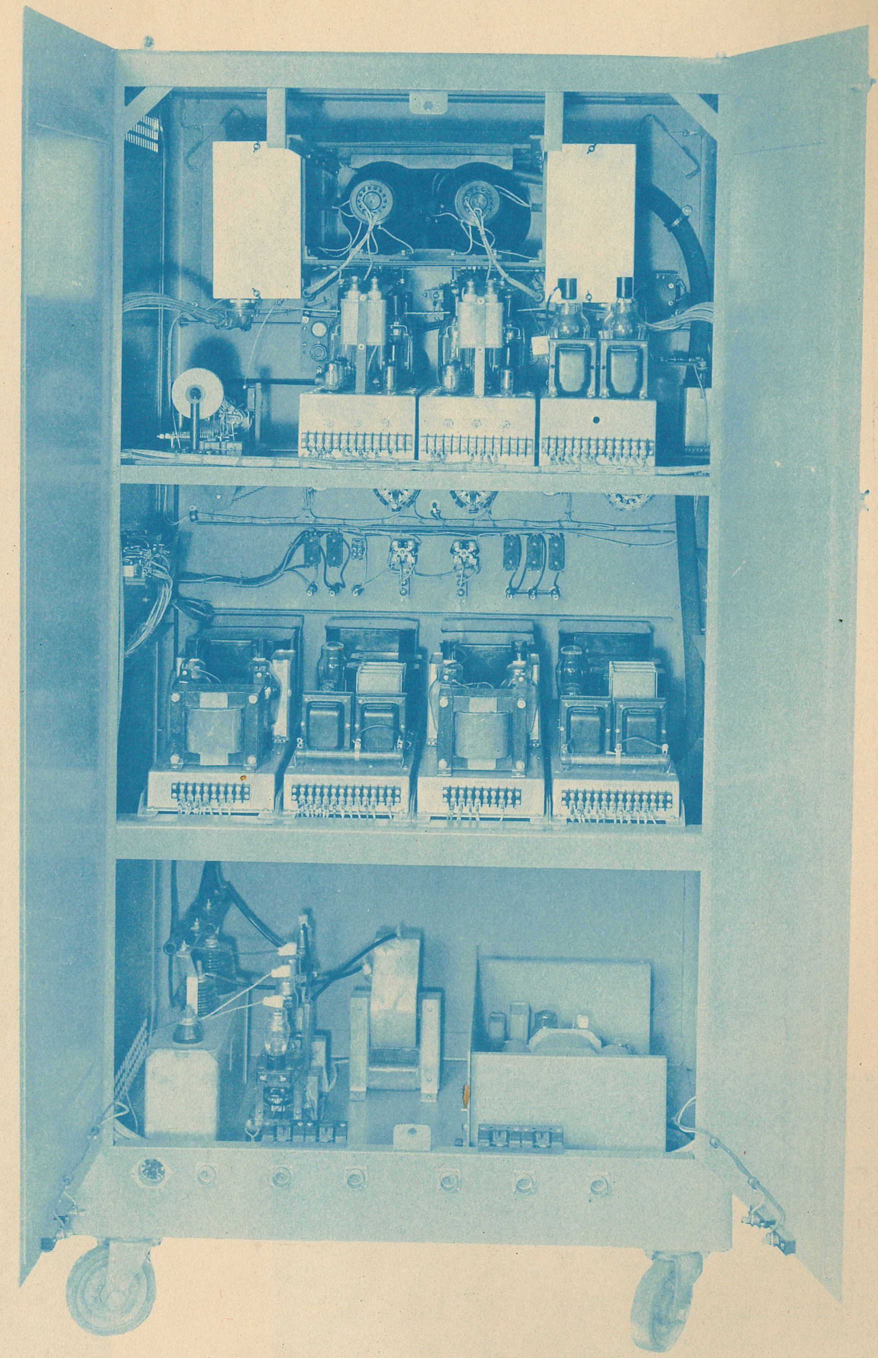




60 326 G-E CATHODE-RAY OSCILLOGRAPH TYPE HC-25-A3. FRONT VIEW OBLIQUE FROM LEFT.

E369.1

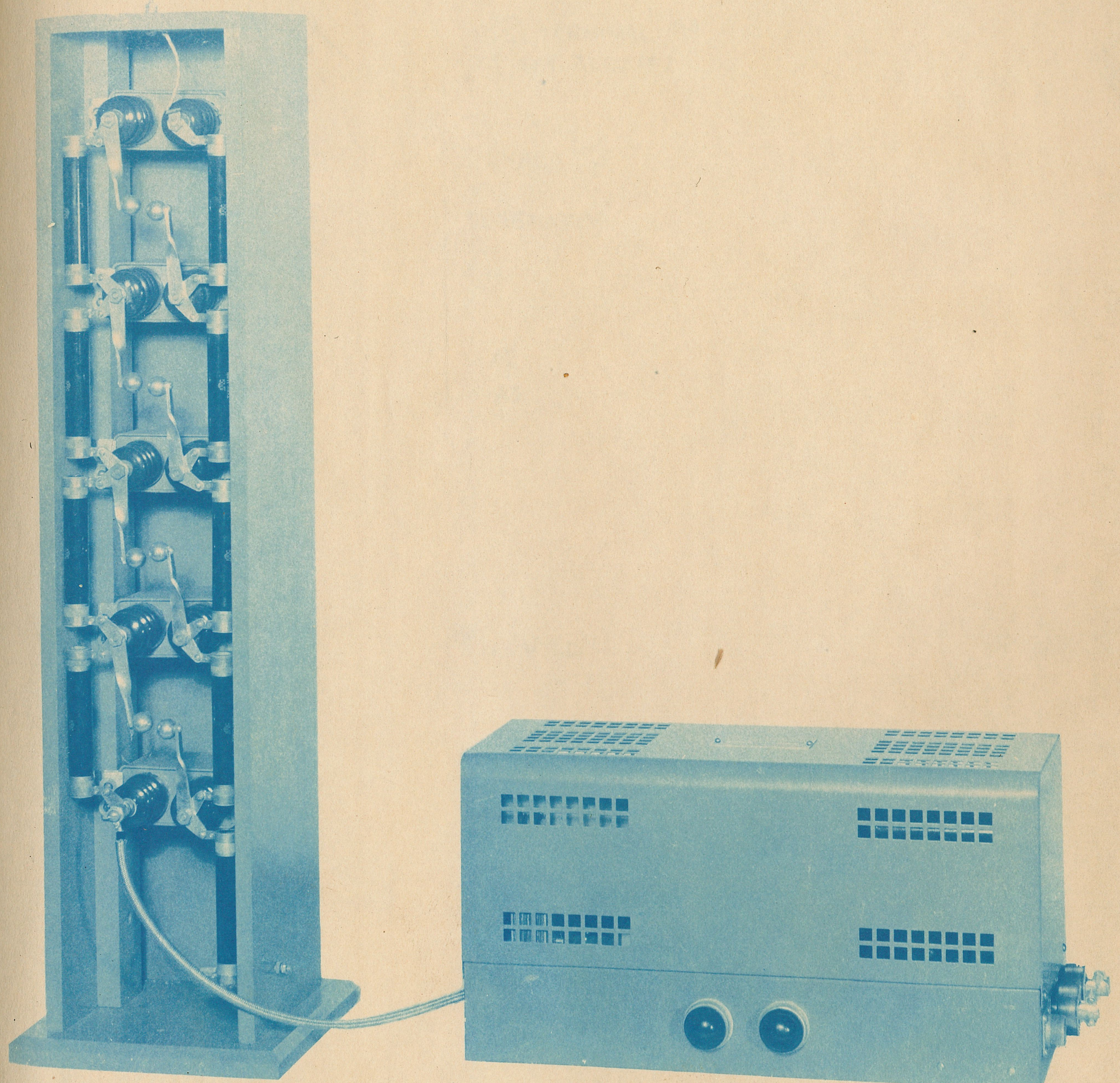
10-22-48



1060 327 G-E CATHODE-RAY OSCILLOGRAPH TYPE HC-25-A3. DOORS OPEN. REAR VIEW.

E369.1

10-22-48



1054 619 TRIP-CIRCUIT UNIT AND TRIP-SURGE GENERATOR, CAT.9159534G1.

537.4 E369.9

6-2-48

GENERAL ELECTRIC

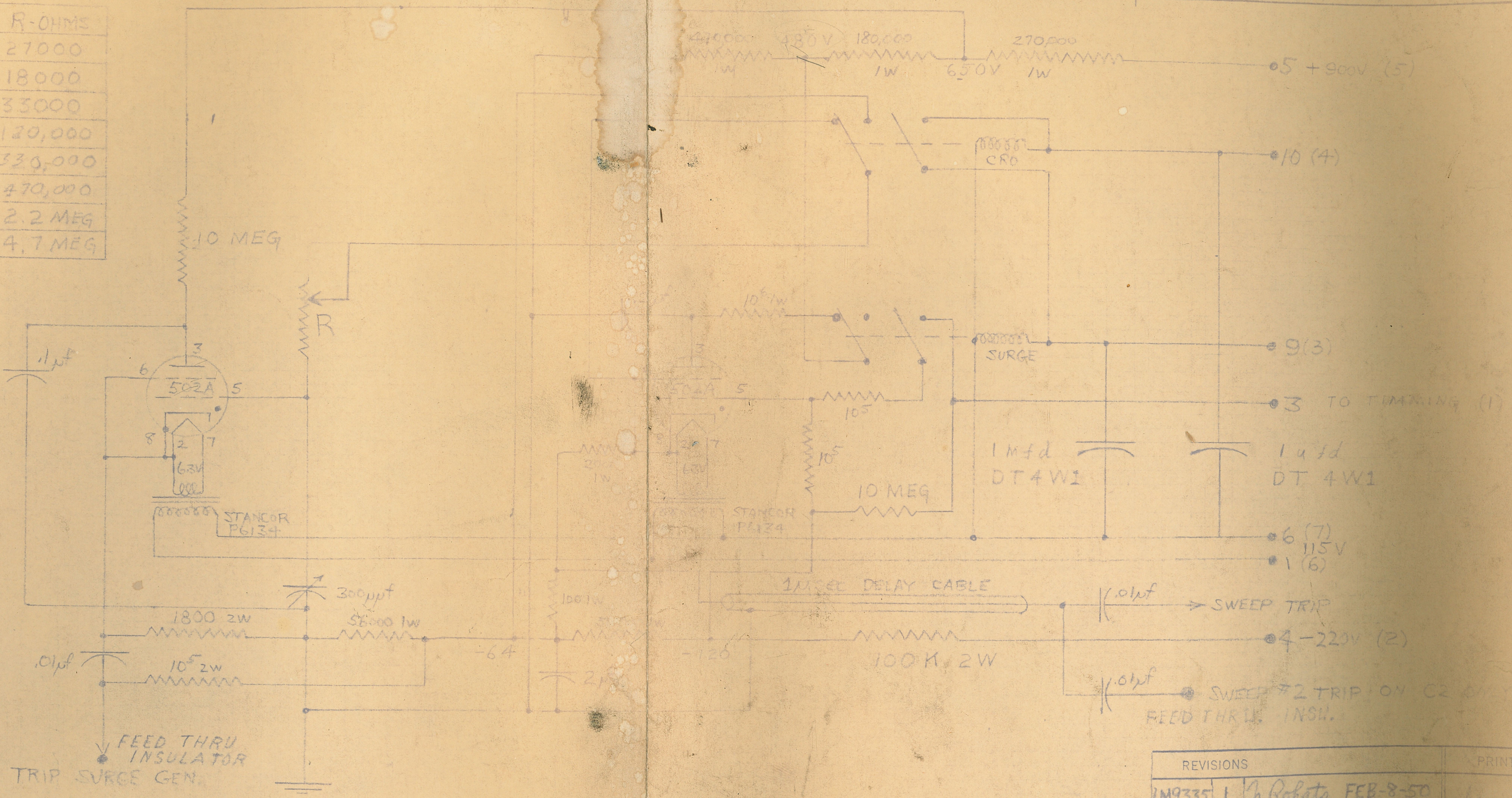
M-5113145

TITLE: TIME DELAY CIRCUIT

FIRST MADE FOR HC-25-C1 & C2 CATHODE RAY OSCILLOGRAPH

F.C.F. on M-5142111

SWEEP MICRO-SEC.	R-OHMS
1	27000
2	18000
5	33000
15	120,000
35	330,000
70	470,000
250	2.2 MEG
1000	4.7 MEG



NOTE – ONLY ONE GROUND POINT

NUMBERS IN BRACKETS FOR HC-25-C4-C5

REVISIONS			PRINTS TO
LM9335	1	N. Rohats FEB-8-50	
LM9368	2	N. Rohats FEB 23-50	
LM9476	3	D. Maure April 1950	
LM	4	D Maure May 1950	
LM1019	5	D Maure Oct [illegible]	

MADE BY [illegible] JAN 20-50

ISSUED Jan 31-50

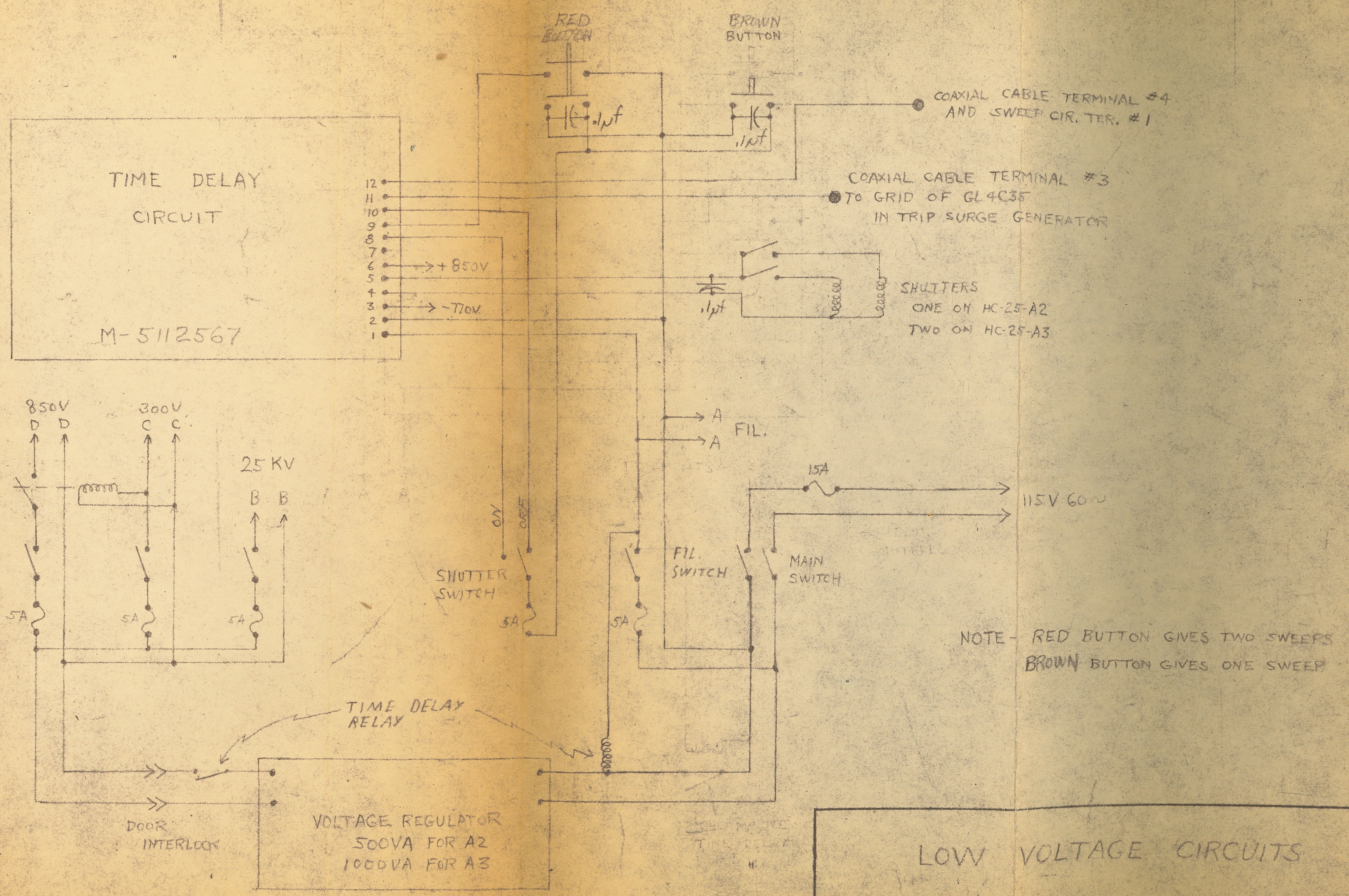
APPROVALS

GEN. ENG. & CONS. LAB. DIV

SCHENECTADY WORKS

M-5113145

CONT ON SHEET SH. NO.



1	R. Rolats July 7-47	LM-6733
	R. Rolats May 28-47	LM-6801
	R. Rolats Aug 22-47	LM 7016
4	R. Rolats Sept 15-47	LM 7074
5	R. Rolats Sept 23-47	LM 7094
6	R. Rolats Nov 25-47	LM 7318
	J. L. Cochran Aug 12-47	LM-7889
8	R. Rolats Oct 25-48	LM-8146

LOW VOLTAGE CIRCUITS

FIRST MADE FOR HC-25-A2 & A3 CATHODE RAY OSCILLOGRAPH

BEGUN BY R. Rolats March 20-47 | TRACED BY

FINISHED BY R. Rolats March 21-47 | INSPECTED T.E. Hagood May 26-47

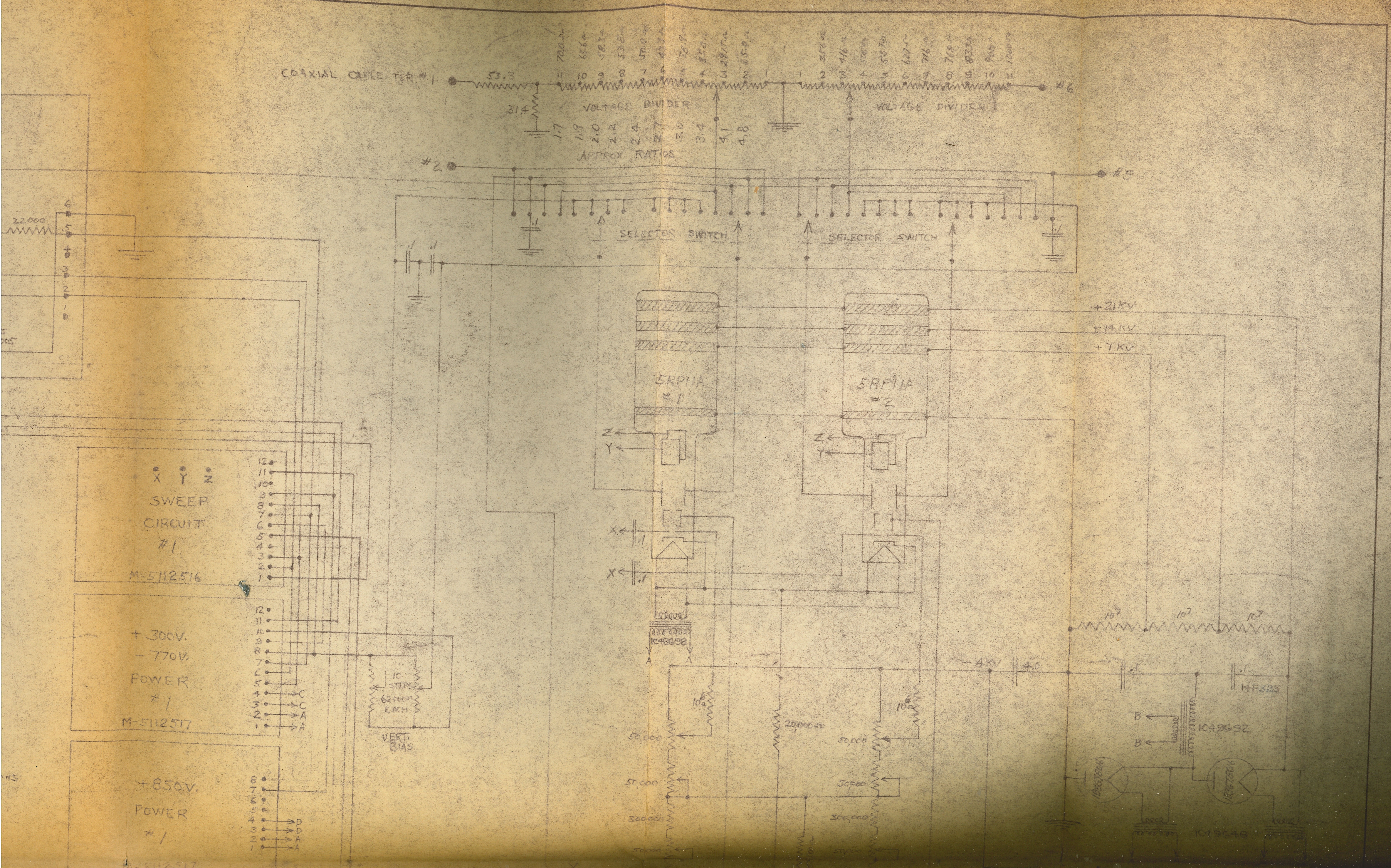
GENERAL ELECTRIC SCHENECTADY WORKS

M-5112518

24[4] 5-2[3] 6-L[2] R PRINTS

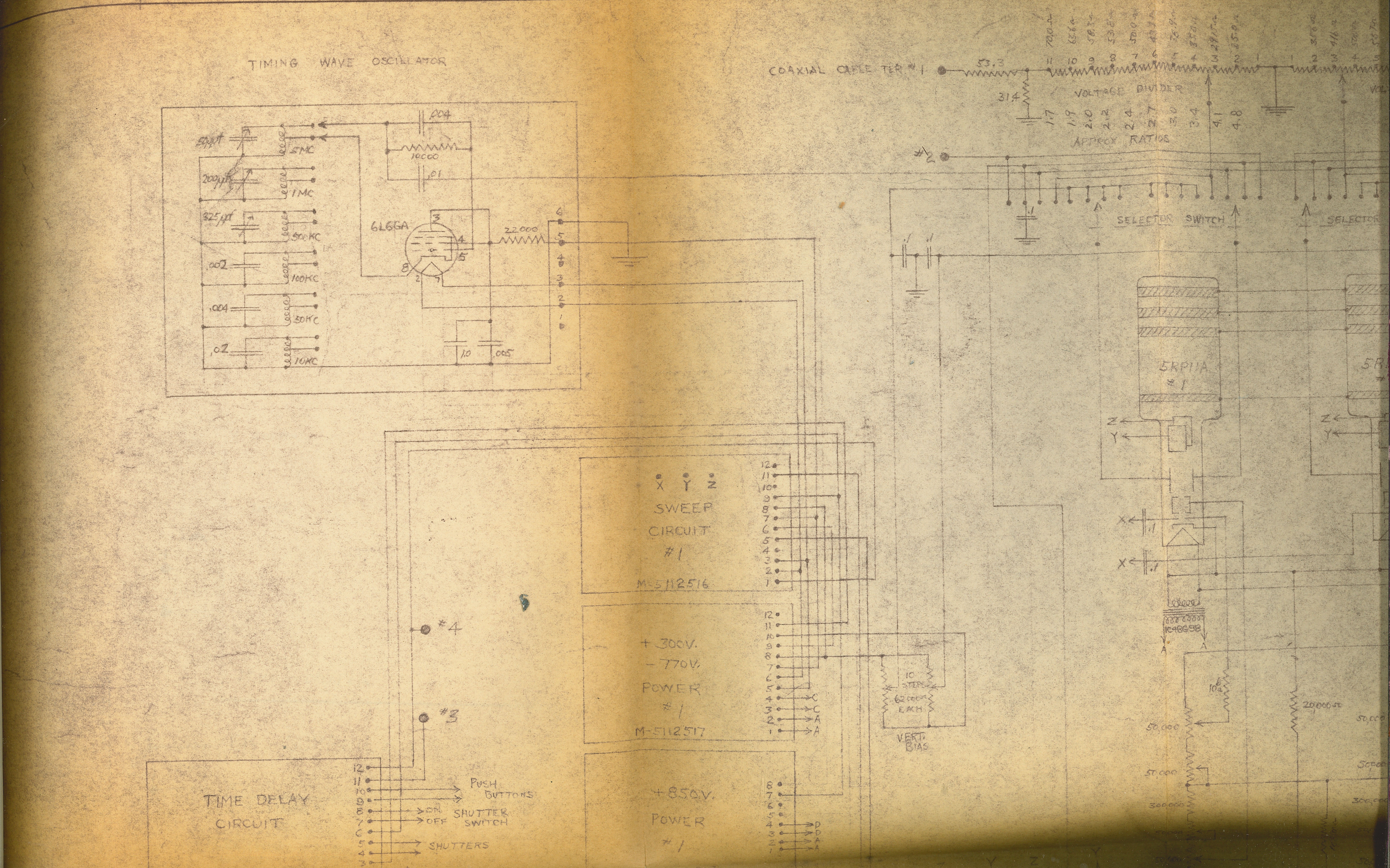
P- 5122173

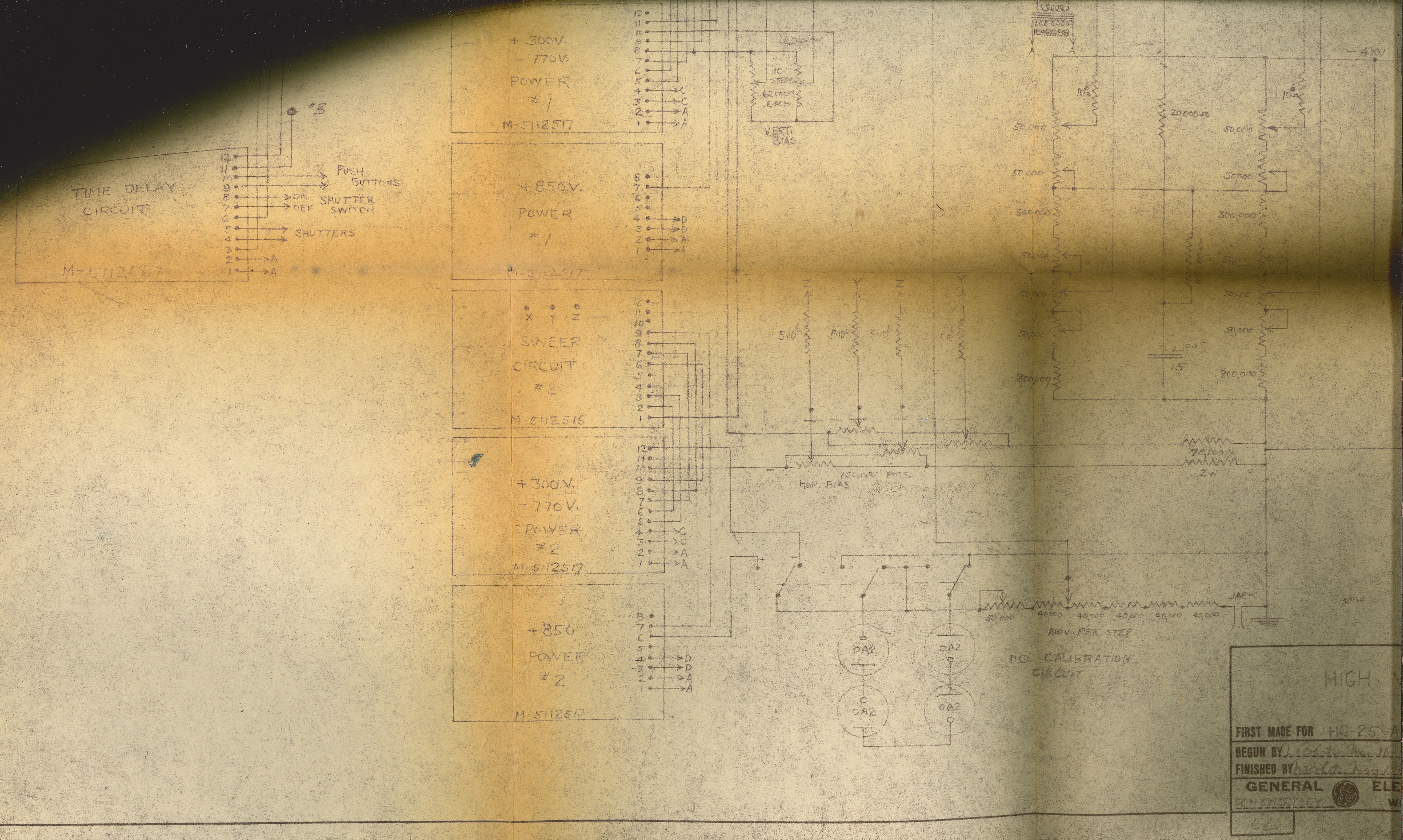
THIRD ANGLE PROJECTION

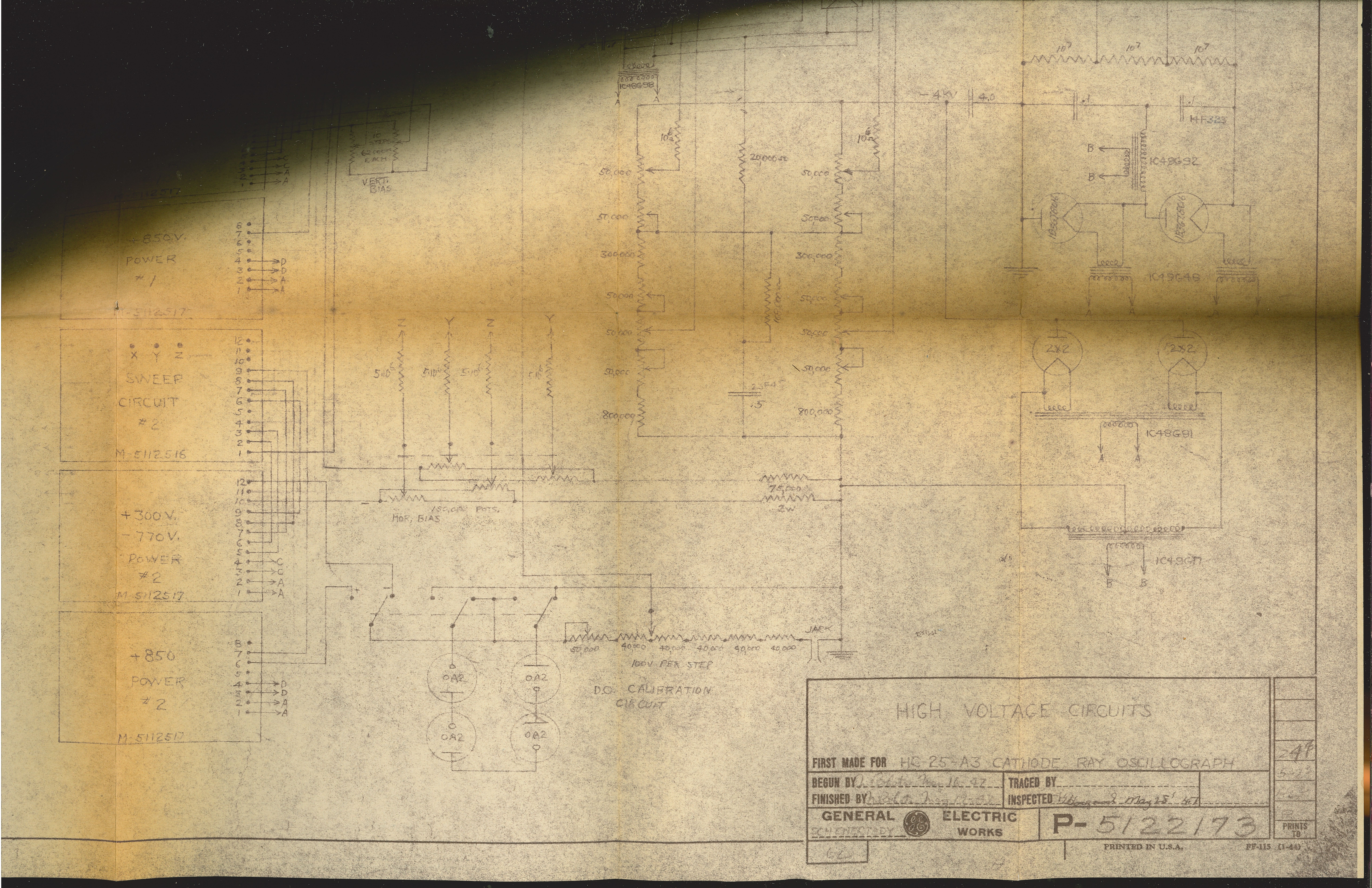


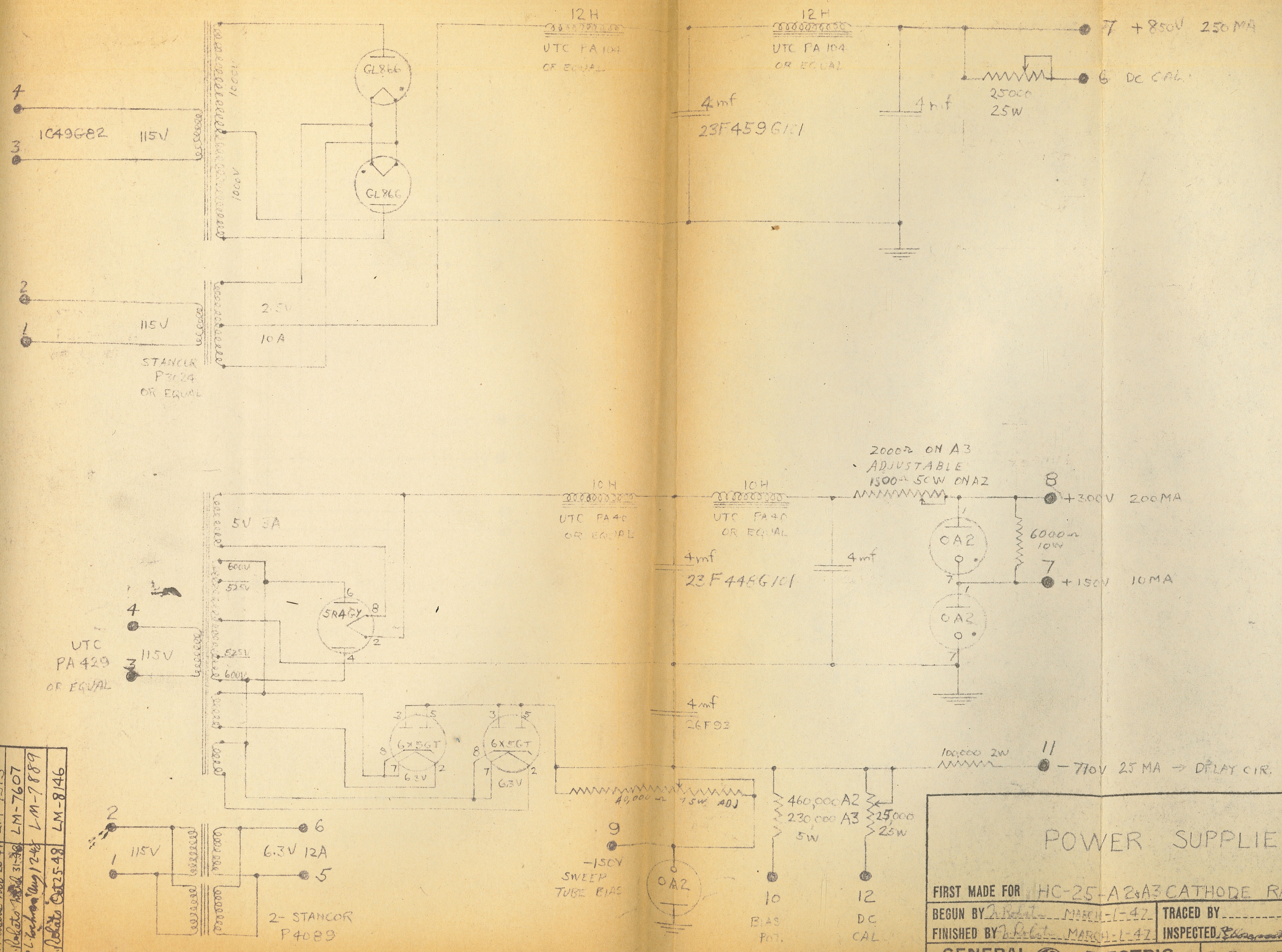
P- 5122173

THIRD ANGLE PROJECTION




TIME DELAY CIRCUIT
M-5112567
#3
PUSH BUTTONS
ON
OFF
SHUTTER SWITCH
SHUTTERS
+300V.
-770V.
POWER #1
M-5112517
+850V.
POWER #1
M-5112517
X Y Z
SWEEP CIRCUIT #2
M-5112516
+300V.
-770V.
POWER #2
M-5112517
+850
POWER #2
M-5112517
10 STEPS
62000Ω EACH
VERT. BIAS
1C486G18
HOR. BIAS
150,000 POTS.
0A2
0A2
0A2
0A2
100V PER STEP
D.C. CALIBRATION CIRCUIT
JACK
-4KV
20,000Ω
75,000
2W
HIGH
FIRST MADE FOR HG-25-A
BEGUN BY
FINISHED BY
GENERAL ELE
SCHENECTADY
62


+850V.
POWER
#1
M-5112517
X Y Z
SWEEP
CIRCUIT
#2
M-5112516
+300V.
-770V.
POWER
#2
M-5112517
+850
POWER
#2
M-5112517
VERT.
BIAS
HOR. BIAS
150,000 POTS.
75,000
2W
D.C. CALIBRATION
CIRCUIT
100V PER STEP
JACK
0A2
2X2
-4KV
1C48G58
1C49G32
1C49G49
1C48G91
1C49G77
HIGH VOLTAGE CIRCUITS
FIRST MADE FOR HC-25-A3 CATHODE RAY OSCILLOGRAPH
BEGUN BY
FINISHED BY
TRACED BY
INSPECTED
GENERAL ELECTRIC
SCHENECTADY WORKS
P-5122173
PRINTS TO
PRINTED IN U.S.A.
FF-115 (1-44)



REVISIONS

1. J. Roberts May 7-47 LM-6733
2. J. Roberts May 28-47 LM-6801
3. J. Roberts Nov 20-47 LM-7313
4. J. Roberts ... 31-48 LM-7607
5. ... Aug 12-48 LM-7889
6. J. Roberts Oct 25-48 LM-8146

POWER SUPPLIES

FIRST MADE FOR HC-25-A2 & A3 CATHODE RAY OSCILLOGRAPH

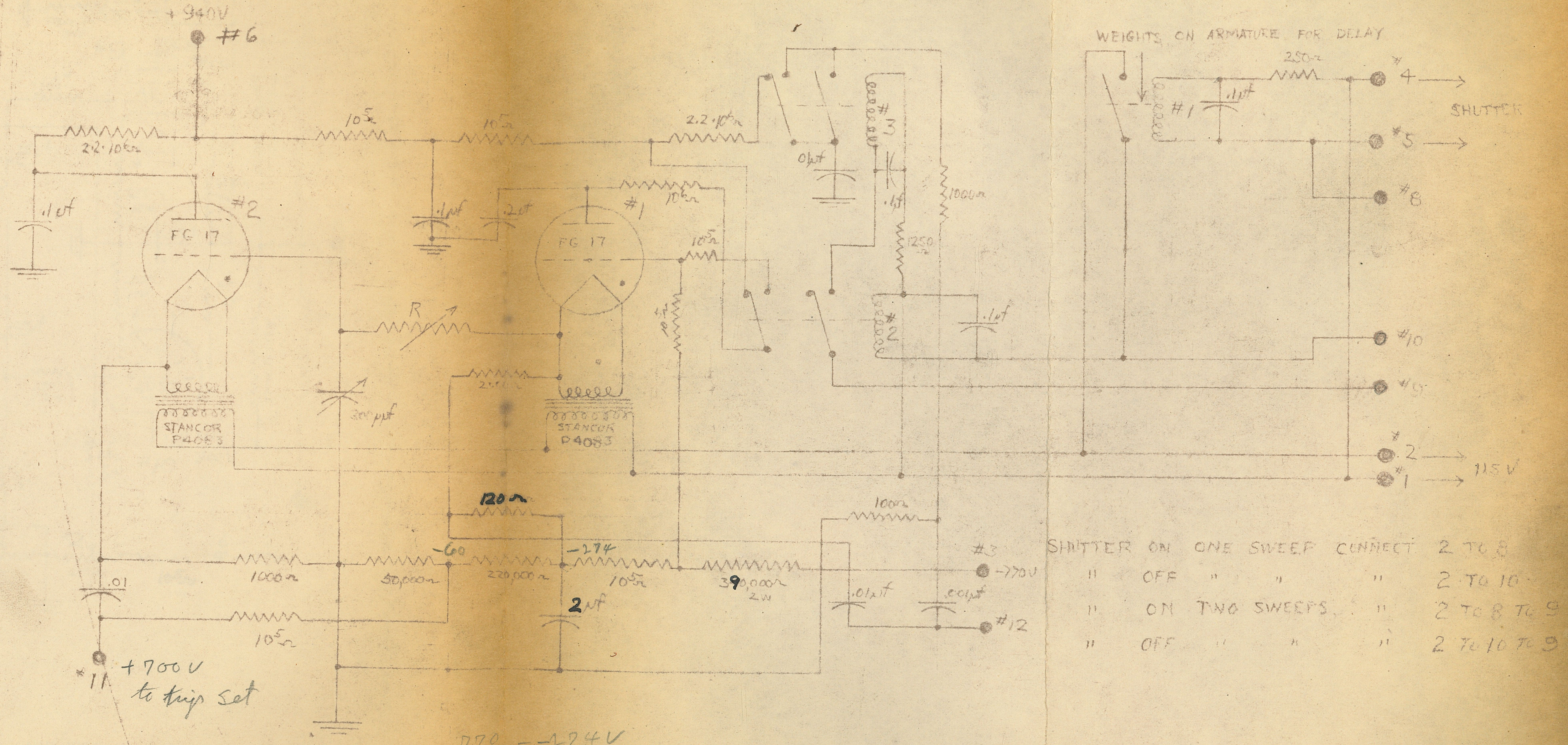
BEGUN BY J. Roberts MARCH-1-47 TRACED BY

FINISHED BY J. Roberts MARCH-1-47 INSPECTED May 26-47

GENERAL ELECTRIC SCHENECTADY WORKS

M- 5112517

PRINTS TO



27/760 × 770 = -274V

SWEEP	R - OHMS
1	1800
2	4700
3	20,000
4	68,000
5	100,000
6	220,000
7	500,000
8	1.5·10⁶
9	2.2 "
10	2.5 "
11	2.7 "

1	H. Roberts Aug 22-47	LM 7016
2	H. Roberts Sept 15-47	LM 7074
3	H. Roberts Nov 17-47	LM-7318
4	H. Roberts Oct 25-48	LM-8146

TIME DELAY CIRCUIT

FIRST MADE FOR HC-25-A2 + A3 CATHODE RAY OSCILLOGRAPH

BEGUN BY H. Roberts May 22-47 TRACED BY

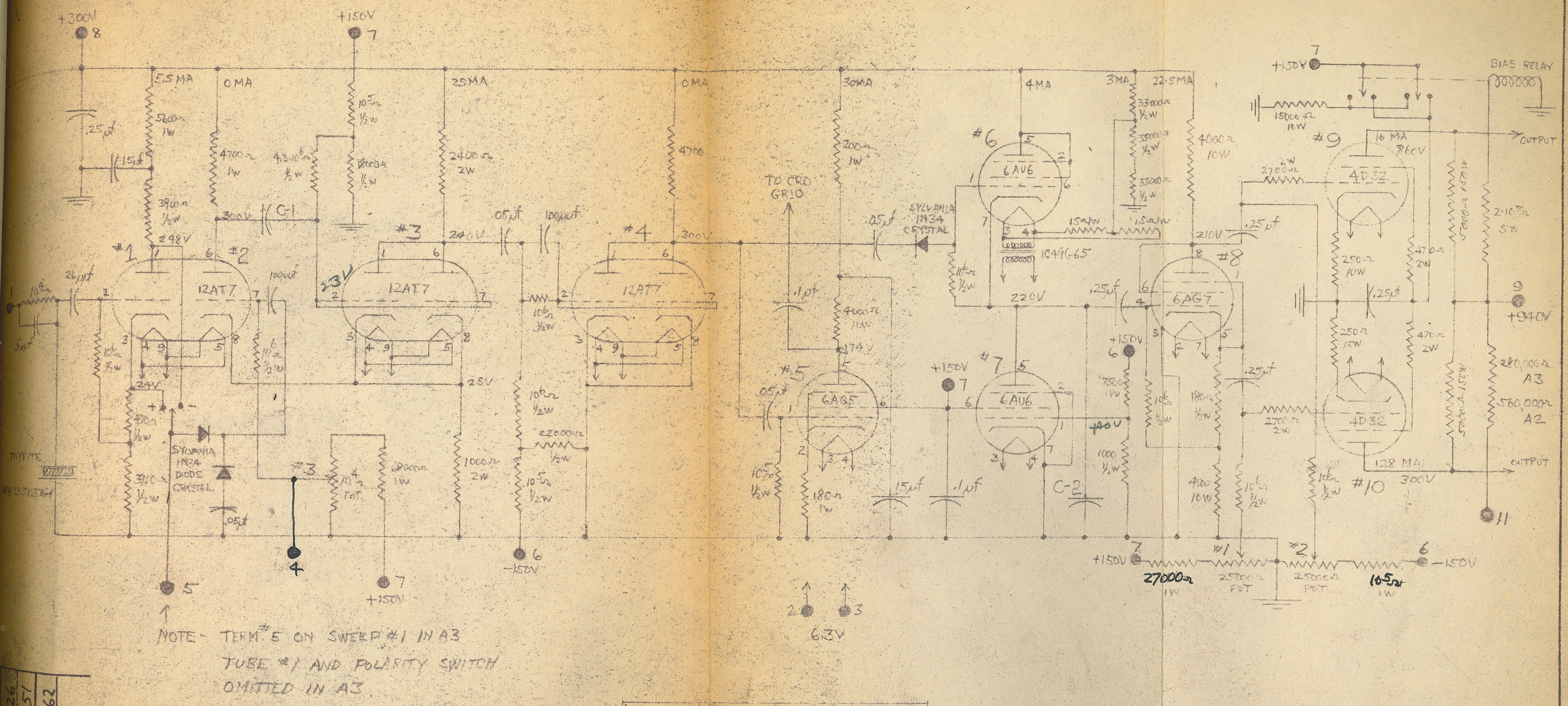
FINISHED BY H. Roberts May 22-47 INSPECTED P. Elwood May 25 '47

GENERAL ELECTRIC
SCHENECTADY WORKS

M-5112567

PRINTS TO

THIRD ANGLE PROJECTION



SWEEP	M.S.	C-1 MMF	C-2 MF
1	1	2	.00005
2	2.5	4.5	.00022
3	6	8	.00062
4	15	20	.0020
5	30	35	.00356
6	60	95	.007
7	150	220	.016
8	400	275	.023
9	1000	400	.12
10	2000	1100	.25
11	5000	3000	.75

NOTE- TABLE VALUES ARE APPROXIMATE AND REQUIRE INDIVIDUAL ADJUSTMENT

SWEEP CIRCUIT

FIRST MADE FOR HC-25-A2 & A3 CATHODE RAY OSCILLOGRAPH

BEGUN BY N. Rohats March 8-47 | TRACED BY N. ROHATS Oct. 15 '48

FINISHED BY N. Rohats March 8-47 | INSPECTED E.E. Graham Oct. 15 '48

GENERAL ELECTRIC SCHENECTADY WORKS

M-5112516

5 23 | 24 4 | GL 2 | R | PRINTS TO

5	N. Rohats	LM-8126
6	N. Rohats	LM-8151
7	N. Rohats Nov 1-48	LM-8162

1000

instruction manual

for

use

of

SORENSEN

A.C.

line

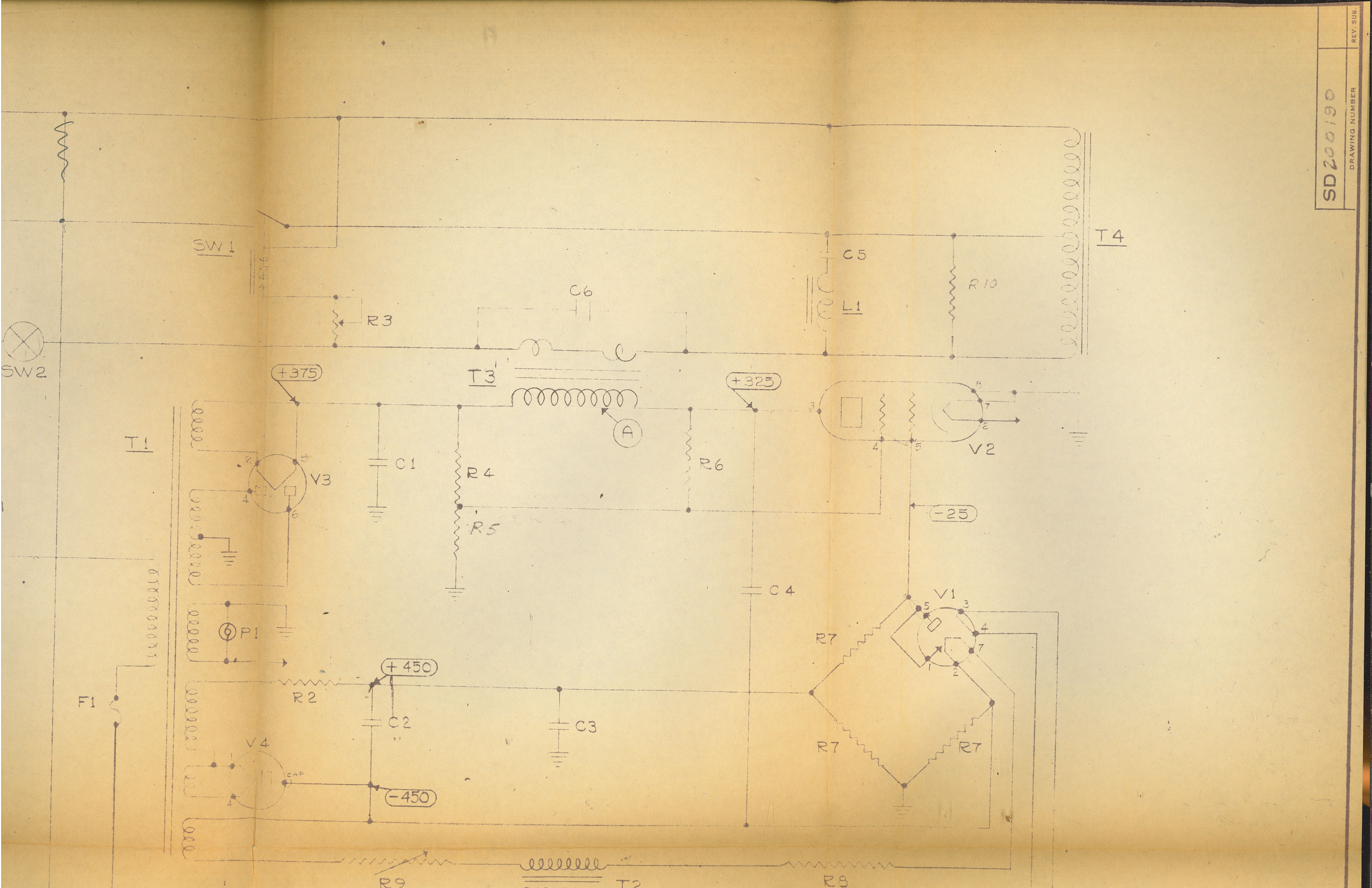
regulators

and

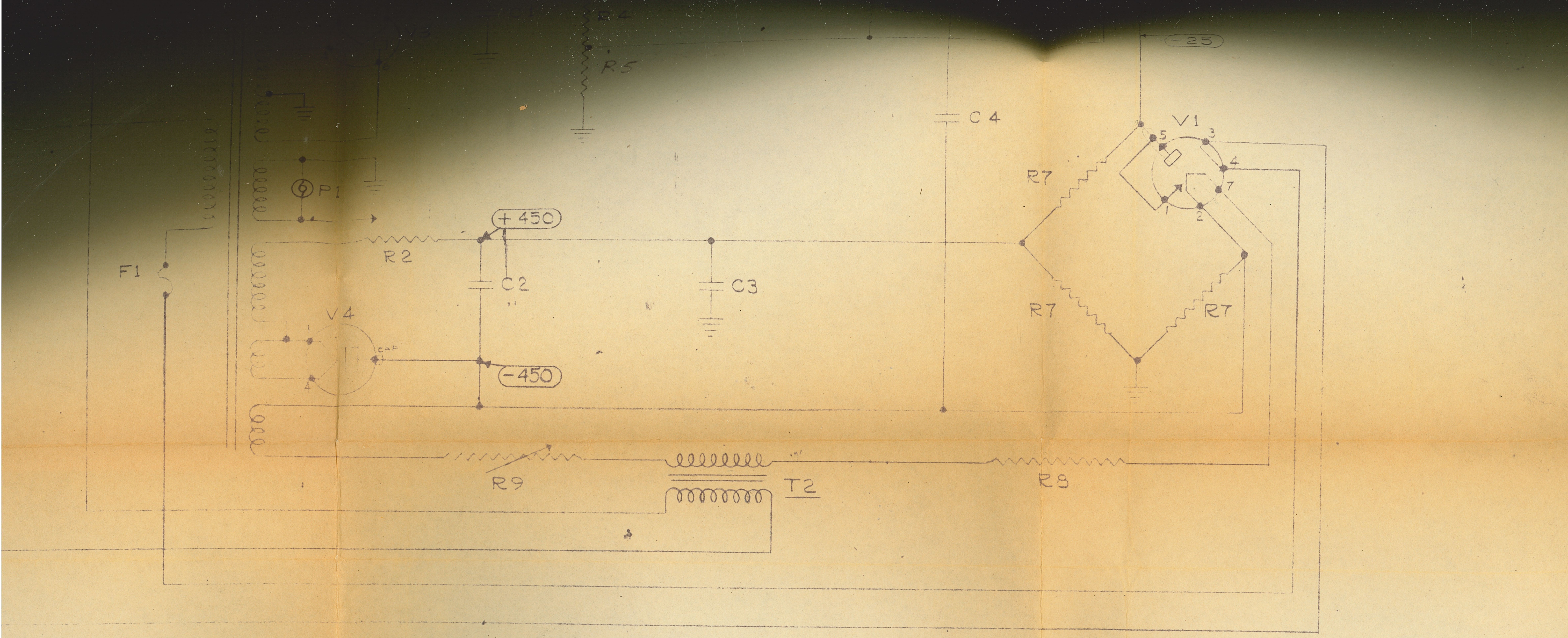
nobatrons

Sorensen and Company, Inc.

Stamford, Connecticut



SW1
SW2
R3
C6
T3
+375
+325
T1
V3
C1
R4
R5
A
R6
V2
C5
L1
R10
T4
-25
C4
V1
R7
R7
R7
P1
+450
R2
C2
C3
F1
V4
CAP
-450
R9
T2
R8
SD200190
DRAWING NUMBER
REV. SUB



TAGE COMP.	R9	1 Ω POT.	C1	4 MFD. 600 V	V1	2AS15
00 Ω ½ W.	R10	500 Ω 50 W	C2	.1 MFD. 1500 V	V2	6L6
00 Ω 50 W. ADJ.			C3	.1 MFD. 1200 V	V3	5Y3
00 Ω } 35,000 RES.	T1	POWER TRANSFORMER	C4	.05 MFD. 1600 V	V4	2X2
00 Ω } TAPPED AT 10,000	T2	COMP. TRANSFORMER	C5	10 MFD. 600 V	L1	THIRD HARMONIC CHOKE
00 Ω	T3	SAT. CORE REACTOR	C6	* 0-4 MFD.	SW1	OVER VOLT. CIRCUIT BREAKER
3 MEG	T4	AUTO TRANSFORMER			SW2	OVER LOAD CIRCUIT BREAKER
DE ADJUST.	F1	1 AMP 3AG FUSE	P1	PILOT LIGHT		

ENCIRCLED VALUES ARE NORMAL D.C. POTENTIALS TO GROUND (CHASSIS) AT 115 VAC INPUT, ~~115~~ VAC OUTPUT, AND 500 VA LOAD.

NOTE (A) - RESISTANCE OF D.C. WINDING APPROX. 2200 Ω

* - ADDED IN TEST AS NECESSARY -

REFERENCE DRAWING NUMBER	
MAT'L.	
FINISH	
SCALE	
BLANK SIZE	

SORENSEN & CO., INC.
STAMFORD, CONN.

SCHEMATIC
MODEL 1000

DRAWN BY: E.P.G.T.E.	DATE: 6-15-48	ELEC. DESIGN APPR. BY-DATE: F.R.S. 6-?-48
CHECKED BY: BOHRER	DATE: 6-25-48	APPROVED BY / DATE
DRAWING NUMBER: SD 200-190		REV. SUB-LET

your **SORENSEN** *instrument . . .*

Before you begin to use your new Sorensen instrument, please read this instruction book very carefully.

The Sorensen Regulator or Nobatron is a precision instrument. This does not mean that your Sorensen instrument will not stand rough handling — it will. How much, will, of course, depend on your own experience and good judgement. You have chosen the Sorensen unit over all other similar types of equipment for any of the reasons listed below —

- Wide input range
- Precise regulation accuracy
- Excellent wave form
- Insensitivity to line frequency fluctuations
- Adjustable output voltage
- Fast recovery time

The experience and "know-how" that has made Sorensen the first line of STANDARD electronic voltage regulators stands behind this instrument. If, for any reason, difficulties are encountered, notify the factory at once . . . DO NOT ATTEMPT ADJUSTMENTS OR REPAIRS WITHOUT FIRST NOTIFYING THE FACTORY. DO NOT TAMPER WITH ANY OF THE COMPONENTS. UNINSTRUCTED TAMPERING WITH ANY OF THE COMPONENTS WILL VOID YOUR GUARANTEE FOR THAT PARTICULAR PART.

requests for information and service . . .

All questions concerning the operation or malfunctioning of this instrument should be directed to the Service Department, Sorensen & Company, Inc., 375 Fairfield Ave., Stamford, Connecticut.

Sorensen & Company, Inc. has adopted a sales and service policy which is meant to be a protection to you as purchaser, and Sorensen & Company, Inc. as supplier.

inspect instruments at once for shipping damage . . .

All shipments should be inspected by the buyer upon delivery and in the event of damage in transit, a claim should be filed against the carrier at once.

warranty . . .

Defective instruments or defective components found in the instruments will be considered for adjustment only if Sorensen & Company, Inc. is notified within the Warranty period specified. The period of Warranty (with the exception of the tubes) for this instrument is one year from date of your acceptance.

The instrument and materials are warranted against defective workmanship and construction, and no other warranty may be implied.

The warranty only covers equipment that is maintained in proper condition and is used by you in a skillful and proper manner. No other warranties may be implied.

procedure for returning damaged or defective material . . .

In order to obtain an adjustment for defective materials, the following procedure should be followed:

A. A request should be made directly to the Service Department of Sorensen & Company, Inc. for authorization to return the defective instrument. It is necessary to list the following information so that your request can be serviced as quickly as possible.

1 *The order number on which the instrument was shipped.*

2 *Model number and serial number of the instrument.*

3 *A brief description of the reason for rejection.*

B. It will be determined by the Service Department of Sorensen & Company, Inc. whether a repair will be attempted at your plant by one of our Field Engineers or Representatives. If this is to be done we will notify you immediately and make arrangements for a visit to your plant. If we indicate that the material is to be returned to our Plant for repair or replacement, a RETURN MATERIAL TAG which outlines shipping procedure will be sent to you.

procedure for returning damaged or defective material (continued) . . .

Defective materials returned to us without RETURN MATERIAL TAG will be sent to us entirely at the risk of the customer. Repair of this instrument might be delayed if an unauthorized return is made.

C. This instrument should be packed as carefully for return as when originally received. The instruments are precision equipment and in many cases very heavy. Transformers and other heavy components should be carefully blocked.

D. If the instrument to be returned is mounted in a cabinet, remove from the cabinet and only return the instrument. Under no circumstances (without the specific instructions from Sorensen & Company, Inc.) return both.

1 *Ratings:* All ratings of units are to be found on the enclosed schematic diagrams.

2 *Description:* A. On most models a pilot light on the front panel indicates that the electronic control circuit is receiving power and that the regulator should be functioning.

B. The Screw driver adjusted control permits adjustment of output voltage setting.

C. Various methods are used in the different models to obtain input and output voltages. On some units, a line cord and plug assembly is provided for input connection. Output voltage is then taken from a dual female receptacle. On other models, the input and output terminals are to be found on the chassis. To eliminate any confusion, reference should be made to the schematic diagram enclosed. Inter-chassis connections for Nobatrons made up of more than one chassis can be found on the block diagrams enclosed.

D. With the exception of the Sorensen diode, all tubes are common commercial types. Diode replacements may be obtained from Sorensen & Company, Inc.

3 *Comments:* The unit is intended to operate within the loads indicated on the accompanying schematic diagram Regulation accuracy is maintained to some degree below minimum load; however, the rated accuracy is not guaranteed except as noted.

If measurements of output voltage are taken for purposes of checking the accuracy of regulation, true rms reading voltmeters should be used, as the regulator regulates the rms value of the output voltage. Rectifier or vacuum type voltmeters are not suitable for this purpose. Measurements should be made directly at the output terminals and not at the end of a line leading to the load. The regulator will deliver constant voltage to its terminals regardless of load changes, but will not compensate for drop in the external wiring.

4 *Principle of operation:* The operation of the unit can best be understood by referring to the schematic diagrams included.

The basic power circuit is shown in heavy lines and includes an autotransformer T4 and a saturable core reactor T3. The reactor is in series with the primary of the autotransformer across the input terminals. Variation of the impedance of the saturable core reactor will vary the voltage impressed on the primary of the autotransformer and consequently will vary the output voltage.

A decrease in reactor impedance, for instance, will increase the portion of the input voltage impressed on the autotransformer primary and will result in an increase in output voltage. Conversely, an increase in reactor impedance will result in a decrease in output voltage.

All that is necessary to achieve voltage regulation is some automatic method of varying the reactor impedance by the right amount to restore the output voltage to its original value at such times as it may vary due to changes in load or input voltage. This action is accomplished by the electronic control circuit.

The basic voltage sensitive element of the Nobatron is the Wheatstone Bridge. One arm of the bridge consists of the diode V1, the filament of which is lighted by the output voltage.

The diode is operated at a temperature limited condition. With this arrangement, a small increment of output voltage results in a change in cathode emission and a large change of plate resistance in the diode. The signal voltage of the bridge is applied to the grid of beam power tube V2 which controls the DC saturating current of the reactor.

A typical sequency of operations is as follows: Assume a rise in output voltage as a result of reduced load or a rise in input voltage. Increased output voltage results in increased voltage and heating of the diode filament. With increased heating, the diode cathode emission increases reducing the plate resistance of the tube. Since the diode forms an arm of the bridge, a change in plate resistance will change the balance condition of the bridge; in this instance the change results in a more negative potential applied to the grid of V2. The more negative grid signal results in a sharp drop in the plate current of V2 and consequently, reduced saturation of the reactor. Reduced DC saturation of the reactor results in an increase in DC impedance which, as pointed out before, lowers the output voltage.

The above action will continue until an equilibrium is reached wherein the net change in output voltage is sufficient to compensate for the changed circuit conditions in the control circuit. The gain of the control system is of such magnitude that the unit will maintain output voltage within the tolerance indicated on the schematic diagram while compensating for the rated range of input voltage and load variations.

Tubes V3 and V4 found in most models, are rectifier tubes in the DC power supplies for the saturating circuit and diode bridge circuit respectively.

Adjustment of output voltage is accomplished by the potentiometer in the circuit supplying the diode filament. Variation of resistance in this circuit varies the value of output voltage required to obtain a given diode filament temperature, and consequently will control output voltage.

The resistor shown connected between the plate and screen of tube V2 (across terminals 9 and 10 in high capacity models) is a swamping resistor to absorb inductive surges originating in the DC reactor winding. The winding has a very high inductance.

When the regulator is first turned on, electronic circuit elements are cold and a period of approximately 60 seconds is required for the unit to reach operating temperature. During this period, the output voltage will be low; however, as the tubes begin to conduct, the output voltage rapidly rises to its proper adjusted value. This is a normal condition and in no way indicates any malfunctioning of the regulator.

5 *Maintenance and Trouble Shooting:* During normal life, the unit requires no maintenance or servicing other than the care usually afforded this type of equipment. Vacuum tubes should be replaced at the end of their specified life in accordance with the policies established for the particular application.

In the event of malfunctioning of the unit due to deterioration or failure of any of its component parts, a systematic checking procedure will provide the quickest and surest method of locating the difficulty. Par. 3 gives systematic checking procedures which should be followed in locating sources of trouble. Fig. 1 gives the voltages which should exist in various parts of the circuit during normal operation. These voltages should be measured with an electronic type voltmeter.

NOTE: DANGEROUS VOLTAGES EXIST IN THE CONTROL CIRCUITS. OBSERVE APPROPRIATE PRECAUTIONS.

Trouble shooting: A. No output voltage. *This condition indicates an open in the power circuit.*

1. Check that the On-Off control is in the "ON" position.
2. Check autotransformer, AC reactor coils, circuit breaker, power leads, and terminals for continuity.

B. No Regulation and Low Output Voltage With Load. *This condition indicates the failure of the electronic control circuit to supply saturating current.*

1. Check the fuse in the control circuit. Replace *only* with a similar type.
2. Inspect tube filaments to see that they are lit.
3. Check tubes in a tube tester.
4. Check the DC power supply to the saturating circuit by checking the value of DC voltage. No voltage will indicate a failure of the transformer winding or of the filter condenser.
5. Check the plate voltage and grid voltage of the beam power tube V2. If the grid voltage is abnormally negative and causing cut off, check the diode bridge supply voltage and the diode filament supply voltage.
6. Check the DC reactor winding for an open.
7. Check the over-voltage circuit breaker if one is used in your unit.
8. In the case of split-chassis construction, check the inter-chassis terminal boards for secure and correct connections.

Trouble shooting (continued): C. No Regulation and High Output Voltage. *This condition indicates that the control circuit is oversaturating the reactor. It may also be the result of shorted turns in the reactor AC coils.*

1. Check to see that the diode filament is lit.
2. Check tube V2 in a tube tester or replace with a spare.
3. Check the bridge signal voltage. If this voltage is abnormally positive, check contacts, connections and resistance values of all components of the bridge. Check diode or replace with a spare.
4. Check the voltage adjusting potentiometer for dirty contacts.

D. Drift with Age of the Range of Output Voltage. *This condition indicates a variation of tube characteristics with age.*

1. Check tubes and replace accordingly.

E. Reduction of Regulation Range or Poor Regulation in General. *These conditions may be the result of deterioration or failure of various components of the control circuit.*

1. Check tubes or replace with spares.
2. Check the DC power supply voltages.
3. Check for shorted turns in the reactor DC coil using an ohmmeter.
4. Check the control circuit in general for loose connections, shorts or damaged parts.
5. Check voltage and resistance values. Check condensers for continuity.

In the event of serious trouble or damage to the unit, return it to the factory for repair and readjustment.